SEE Testing of LTC1419 Analog to Digital Converter.

Texas A&M University Cyclotron
June 2004

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1. Purpose

The LTC1419 was tested for its sensitivity to single event effects induced by heavy-ion irradiation at Texas A&M University (TAMU) Cyclotron. The goal of the test was to determine whether the part was sensitive to single event effects, such as single event latchup (SEL), single event upset (SEUs) and single event functional interrupts (SEFIs).

2. Parts

The LTC1419 is a 14-bit analog to digital converter capable of operating at 800 ksps while consuming 150 mW from +/- 5V power supplies. The input range is +/- 2.5V. Three samples in packaged in DIPs were tested. There were no date or lot codes on the lids.

3. Test Configuration

Testing was performed with three different static analog input voltages (0.512V, 1.19V and 2.12V) that produced three different fixed digital outputs. For the test, the digital output was compared with the expected digital output supplied by the computer controlling the system. Comparisons were made for each of the 14 digital output bits using 14 separate comparators. In the event of a SEU, the output of the comparator would toggle from low to high. After a suitable delay, a signal would be sent to the FIFO to read the output of the LTC1419 and that value was stored in the computer. In order to measure the length of SEUs, a storage oscilloscope was attached to the comparator output. Figure 1 shows the test configuration used. Testing was done at 500 ksps, which is less than the maximum of 800 ksps. Because of noise in the system, the 5 least significant bits were masked out and only upsets in the 9 most significant bits were monitored and logged.
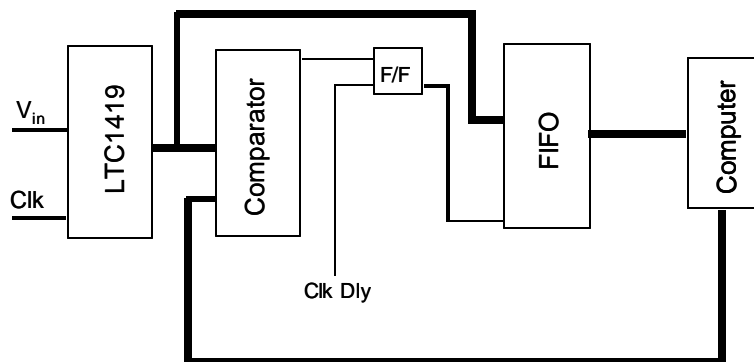

Fig. 1. Test configuration used for capturing SEUs. The fourteen output bits are connected to the inputs of 14 different comparators. The computer sends a 14-bit word to the comparator. The word is the expected output. When there was a miscompare between any of the bits of the ADC's output and the expected output supplied by the computer, the comparator toggled and the output of the LTC1419 was stored in the FIFO.

4. Heavy Ions Used

The following heavy ions were used for SEE testing.

Table 1.
Ions and LETs

Ion	LET $(MeV.cm^2/mg)$
Ne	2.8
Ar	9
Kr	30.2
Cu	21.5
Xe	55.3

Angles of 30° and 45° were also used to increase the effective LET. The fluence for each run was variable because the run was stopped after approximately 100 SEUs had been captured.

5. Results

The following results were obtained:

?? No SELs were observed at the highest LET (78.2 $MeV.cm^2/mg$) to a total fluence of $6.2x10^5$ ions/cm^2 .

?? No SEFIs were observed.

?? SEUs were observed with a LET threshold below 2.8 $MeV.cm^2/mg$ and a saturated cross-section of $1x10^{-3}cm^2$/device. Fig 2 shows the SEU cross-section as a function of ion LET_{eff}. There is a small dependence on input voltage.
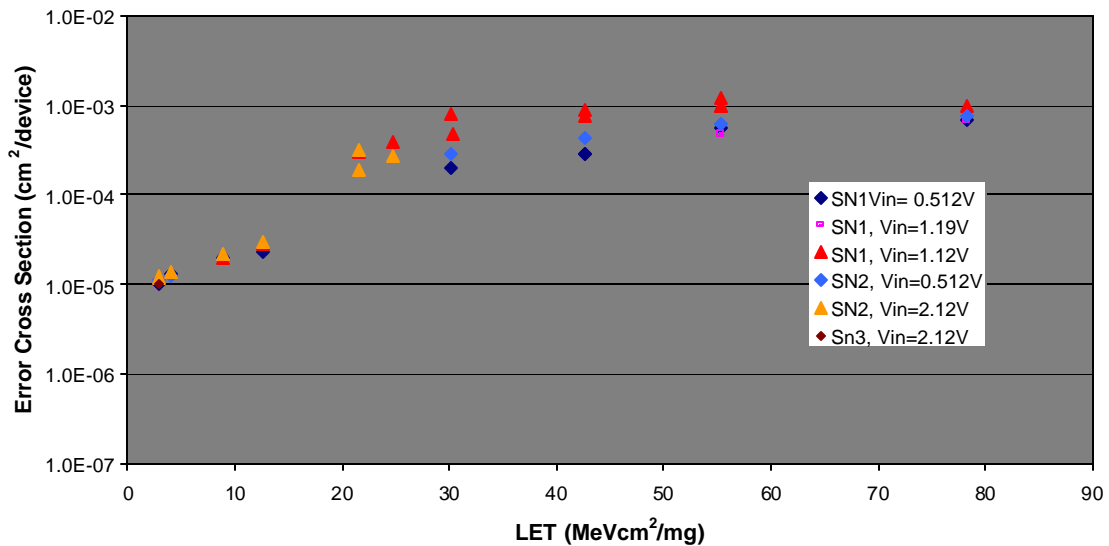

Fig. 2. SEU cross-section as a function of effective ion LET.

SEUs were captured by attaching the probe of a storage oscilloscope to the output of the voltage comparator. Fig. 3 shows a typical trace with a width of 2 microseconds. This is the time it takes for the ADC to complete one measurement when operating at 500 ksps. The trace shows that the ADC recovered after the SEU.
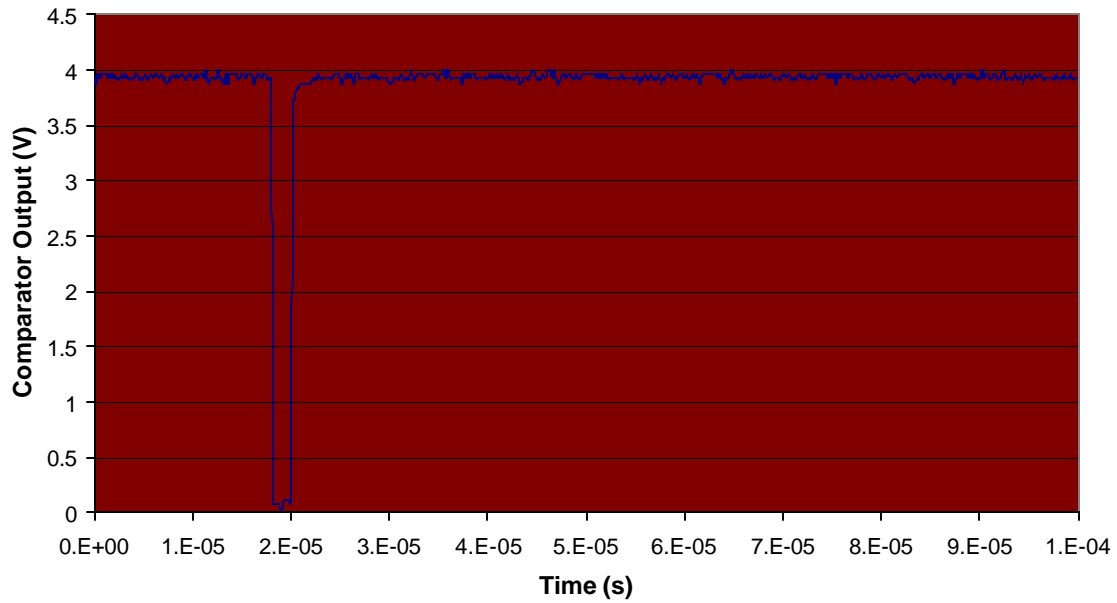

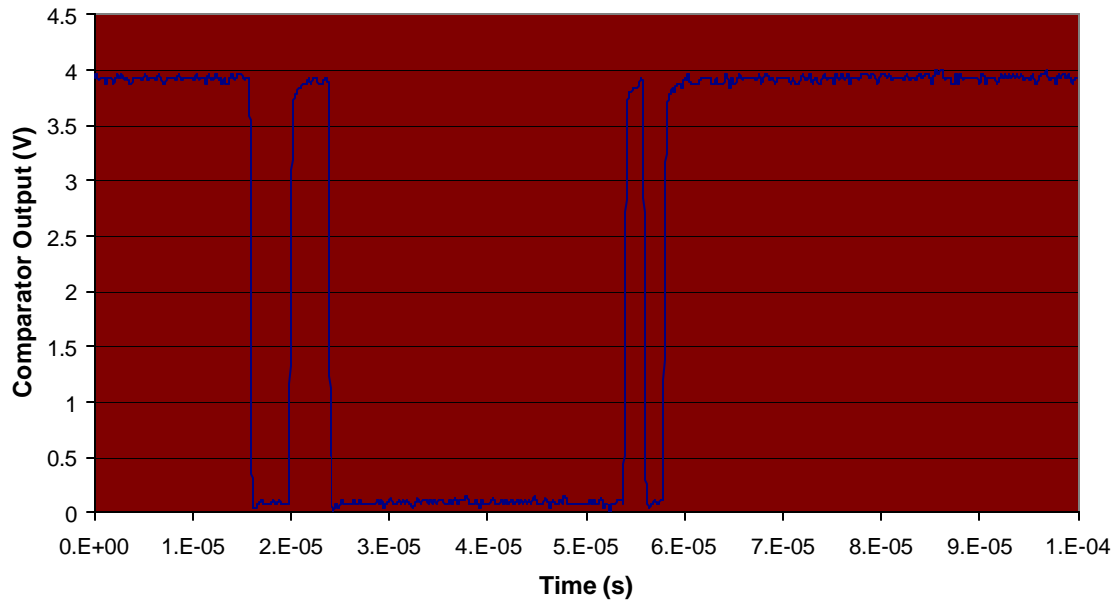Figure 3. Comparator output voltage transient indicating an SEU in the LTC1419 for an ion with a LET of 2.8 MeV.cm^2/mg.

Figure 4. Comparator output voltage transient induced by an ion with an LET of 54 MeV.cm^2/mg. There are three SEUs of varying duration closely following one another.

Multiple SEUs, by which we mean an SEU that lasted more than one conversion cycle, were also captured. Fig. 4 shows three SEUs in rapid succession. The first transient has a width of 4 microseconds, the second 30 microseconds, and the last 2 microseconds. These results imply that the first transient recovers in 2 conversions, the second in 15 conversions and the last in one conversion. The longer transients are only observed with ions of high LET.

6. Calculated SEU rates for SDO

The SEU rate was calculated for the SDO orbit. The results are:

> ?? 0.035 Upsets per device per day at solar minimum,
> ?? 0.0061 Upsets per device per day at solar maximum.

It should be noted that this rate is based on upsets in only the 9 most significant bits so that the rate would be higher if none of the 14 bits was masked out.

Run#	SN#	Vin	Ion	Energy	LET	Angle	LETeff	eff. Fluence	SEUs Counted	SEUs Acquired	X SEU	SEL
1	1	2.12V	Xe	1291	55.3	0	55.3	3.01E+05				0
2	1	2.12V	Xe	1291	55.3	0	55.3	4.35E+04				0
3	1	2.12V	Xe	1291	55.3	0	55.3	2.02E+04				0
4	1	2.12V	Xe	1291	55.3	0	55.3	6.32E+04	62	28	9.81E-04	0
5	1	2.12V	Xe	1291	55.3	0	55.3	6.02E+04	60	26	9.97E-04	0
6	1	2.12V	Xe	1291	55.3	0	55.3	1.23E+05	148	57	1.20E-03	0
7	1	2.12V	Xe	1291	55.3	45	78.2	6.29E+04	62	40	9.86E-04	0
8	1	2.12V	Xe	1291	55.3	45	78.2	1.00E+07				0
9	1	1.19V	Xe	1291	55.3	45	78.2	1.62E+05	108	85	6.67E-04	0
10	1	1.19V	Xe	1291	55.3	0	55.3	2.21E+05	106	87	4.80E-04	0
11	1	0.512V	Xe	1291	55.3	0	55.3	1.77E+05	100	62	5.65E-04	0
12	1	0.512V	Xe	1291	55.3	45	78.2	1.52E+05	103	73	6.78E-04	0
13	2	.512V	Xe	1291	55.3	0	55.3	1.79E+05	108	58	6.03E-04	0
14	2	.512V	Xe	1291	55.3	45	78.2	1.34E+05	100	64	7.46E-04	0
15	2	.512V	Kr	829	30.2	0	30.2	4.41E+05	127	69	2.88E-04	0
16	2	.512V	Kr	829	30.2	45	42.7	2.94E+05	124	65	4.22E-04	0
17	1	0.512V	Kr	829	30.2	0	30.2	5.85E+05	117	80	2.00E-04	0
18	1	0.512V	Kr	829	30.2	45	42.7	4.50E+05	130	87	2.89E-04	0
19	1	0.512V	Kr	829	30.2	45	42.7					0
20	1	0.512V	Kr	829	30.2	45	42.7	3.94E+05	112	81	2.84E-04	0
21	1	2.12V	Kr	829	30.2	45	42.7	2.62E+05	235	100	8.97E-04	0
22	1	2.12V	Kr	829	30.2	45	42.7	2.01E+05	150	70	7.46E-04	0
23	1	2.12V	Kr	829	30.2	0	30.2	3.57E+05	277	101	7.76E-04	0
24	1	2.12V	Cu	642	21.5	0	21.5	4.42E+05	134	63	3.03E-04	0
25	1	2.12V	Cu	642	21.5	45	30.4	2.78E+05	132	62	4.75E-04	0
26	1	2.12V	Cu	642	21.5	30	24.8	3.19E+05	122	63	3.82E-04	0
27	2	2.12V	Cu	642	21.5	0	21.5	5.11E+05	98	50	1.92E-04	0
28	2	2.12V	Cu	642	21.5	30	24.8	1.05E+06	290	133	2.76E-04	0
29	2	2.12V	Cu	642	21.5	0	21.5	1.02E+06	317	134	3.11E-04	0
30	2	2.12V	Ar	471	9.0	0	9.0	4.68E+06	104	103	2.22E-05	0
31	2	2.12V	Ar	471	9.0	45	12.7	4.40E+06	132	132	3.00E-05	0
32	1	2.12V	Ar	471	9.0	0	9.0	1.00E+07	193	194	1.93E-05	0
33	1	2.12V	Ar	471	9.0	45	12.7	3.83E+06	107	107	2.79E-05	0
34	1	0.512V	Ar	471	9.0	45	12.7	4.25E+06	99	99	2.33E-05	0
35	1	0.512V	Ar	471	9.0	0	9.0	5.19E+06	105	105	2.02E-05	0
36	1	0.512V	Ne	258	2.8	0	2.8	1.00E+07	103	103	1.03E-05	0
37	1	0.512V	Ne	258	2.8	45	4.0	1.00E+07	132	129	1.32E-05	0
38	2	0.512V	Ne	258	2.8	0	2.8	1.00E+07	112	111	1.12E-05	0
39	2	0.512V	Ne	258	2.8	45	4.0	1.00E+07	127	125	1.27E-05	0
40	2	2.12V	Ne	258	2.8	45	4.0	1.00E+07	140	136	1.40E-05	0
41	2	2.12V	Ne	258	2.8	0	2.8	1.00E+07	121	120	1.21E-05	0
42	3	2.12V	Ne	258	2.8	0	2.8	1.00E+07	99	99	9.90E-06	0